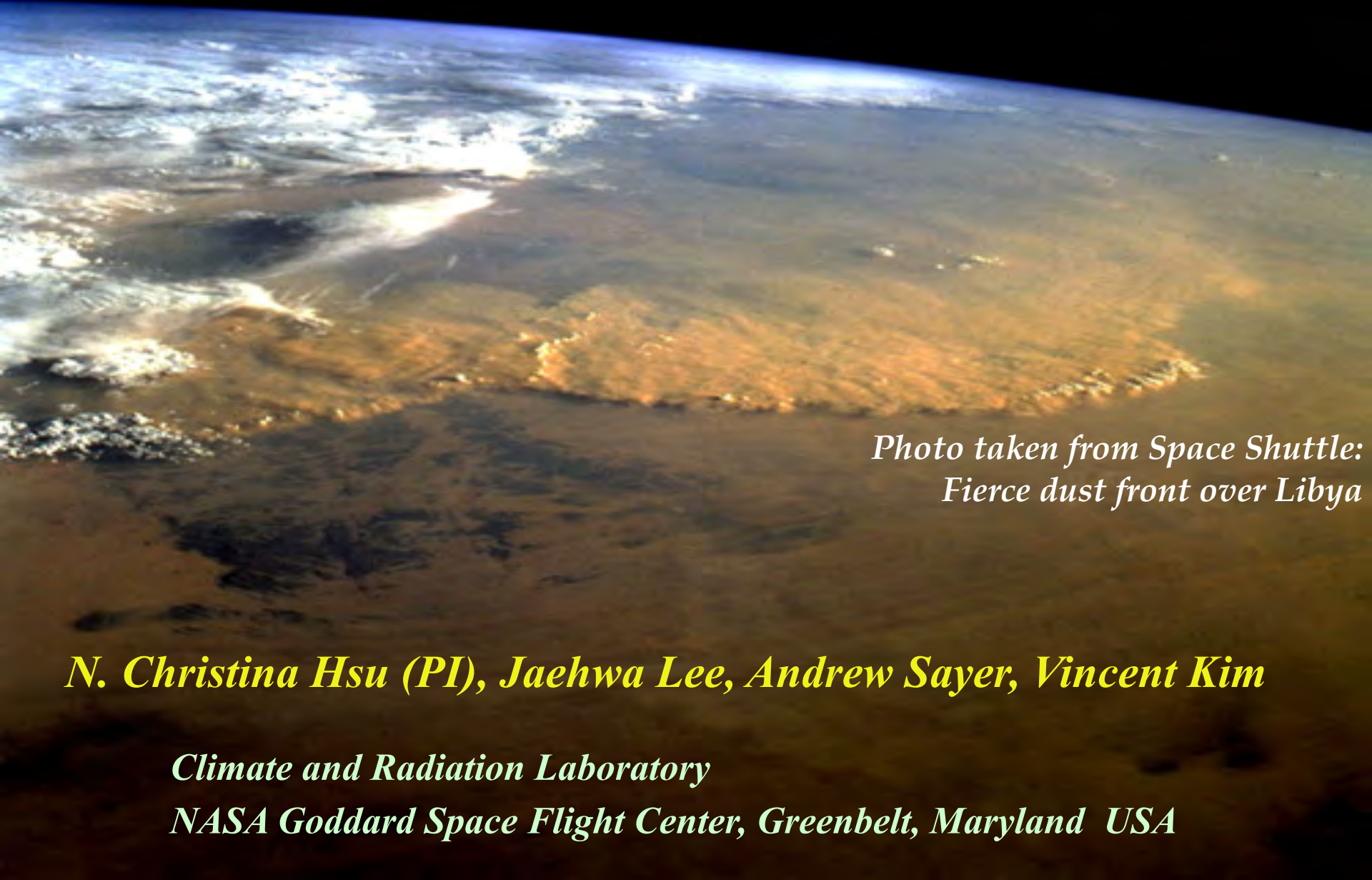


Status Update On Deep Blue Aerosol Algorithm for Constructing Consistent Long-Term Data Records From MODIS To VIIRS



*Photo taken from Space Shuttle:
Fierce dust front over Libya*

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Multi-Sensor Long-Term Deep Blue Aerosol Products

➤ *Science Objectives:*

- Our primary goal is to produce consistent long-term aerosol climate data record using multiple satellite sensor data from **AVHRR** (historic) to **SeaWiFS** and **MODIS** (EOS-era) to **VIIRS** (JPSS-era)
- Our new **VIIRS** aerosol products are generated based upon *Deep Blue* algorithm (over land) (previously applied to **AVHRR**, **SeaWiFS** and **MODIS**) and SOAR algorithm (over ocean) (previously applied to **AVHRR** and **SeaWiFS**)

➤ *Challenges:*

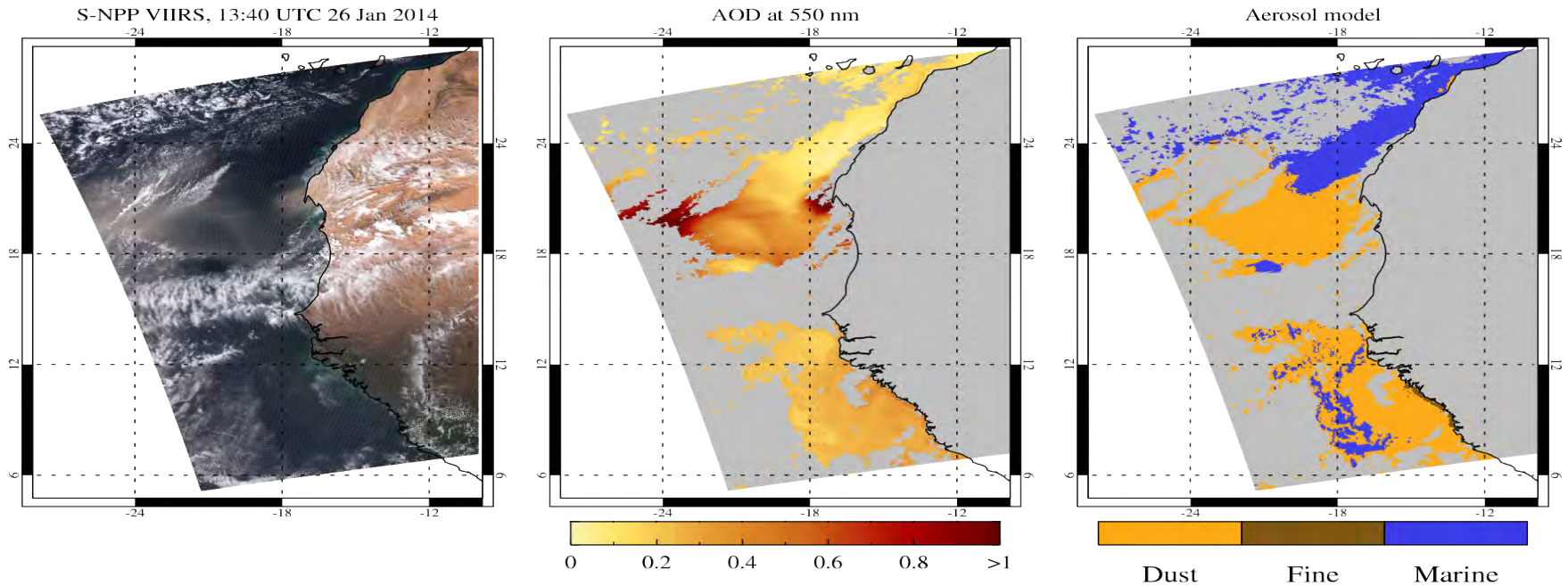
- ✓ **Wavelength differences** in key bands used in *Deep Blue* algorithm: 0.412, 0.470, 0.650, 2.13 μm (MODIS) vs. 0.412, 0.488, 0.670, 2.25 μm (VIIRS)
- ✓ **Radiometric calibration** in solar reflectance channels (additional calibration correction was applied in our VIIRS algorithm to match the MODIS Aqua time series)
- ✓ **Different spatial sampling** (VIIRS has wider swath and more orbital overlaps than MODIS)



Recent Progress on Deep Blue Aerosol Algorithm for VIIRS

- ***Expand coverage from **arid and semi-arid** regions into **vegetated** (SeaWiFS, MODIS C6.1, and VIIRS) areas as well as **oceans** (SeaWiFS and VIIRS only)***
- ***Develop and employ consistent **non-spherical dust models** for aerosol retrievals over land and ocean***
- ***Utilize **spectral curvature approach** to distinguish **smoke aerosols** from **urban/industrial aerosols** and from clouds***
- ***Produce new **aerosol type products** as part of the Deep Blue data suite***

VIIRS ocean retrieval algorithm

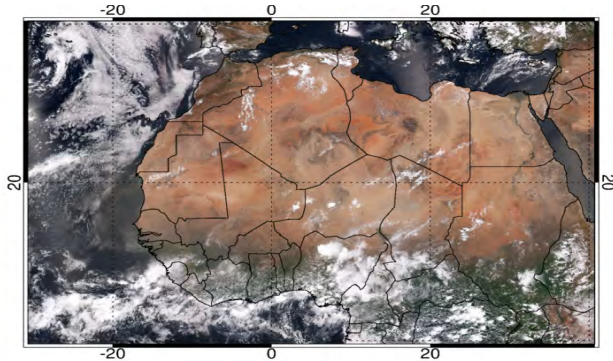


- The VIIRS ocean algorithm is an extension and improvement on our SeaWiFS algorithm
 - Similar in principle to other common approaches (e.g. MODIS) as well
- Retrieve AOD, fine mode fraction (Ångström exponent), aerosol type (from a selection of models)
 - Includes nonspherical dust model
- Cloud screening seems effective even in cases of heavy aerosol loading

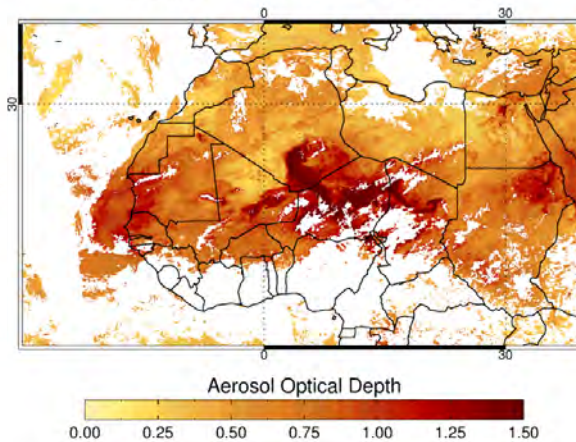
Reference: [Sayer et al., 2017, JGR, “Satellite Ocean Aerosol Retrieval \(SOAR\) algorithm extension to S-NPP VIIRS as part of the ‘Deep Blue’ aerosol project”](#)

Effects of New Dust Optical Models on Land/Sea Discontinuity in Retrieved AOD

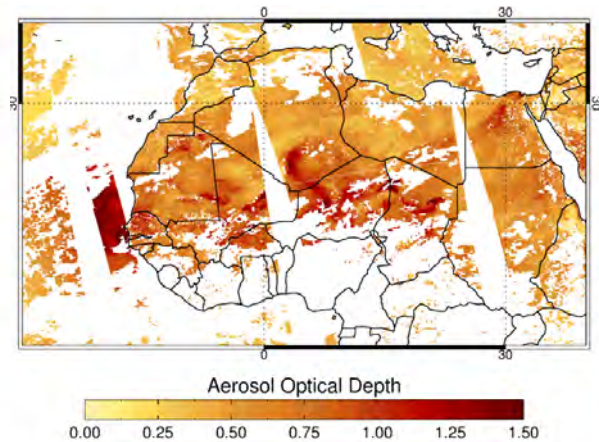
(a) VIIRS RGB image on June 8, 2015



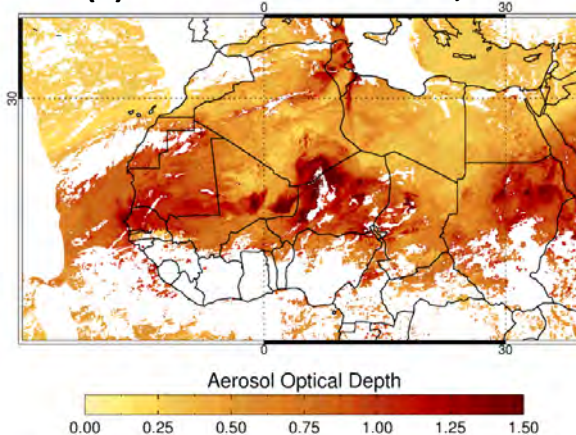
(b) VIIRS AOD on June 8, 2015



(c) MODIS AOD on June 8, 2015

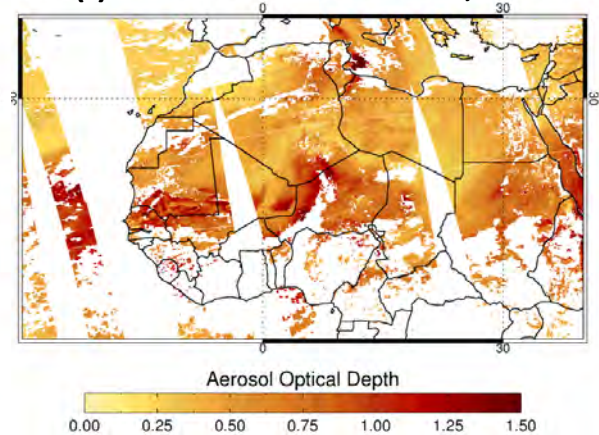


(d) VIIRS RGB image on June 13, 2015



(e) VIIRS AOD on June 13, 2015

(f) MODIS AOD on June 13, 2015

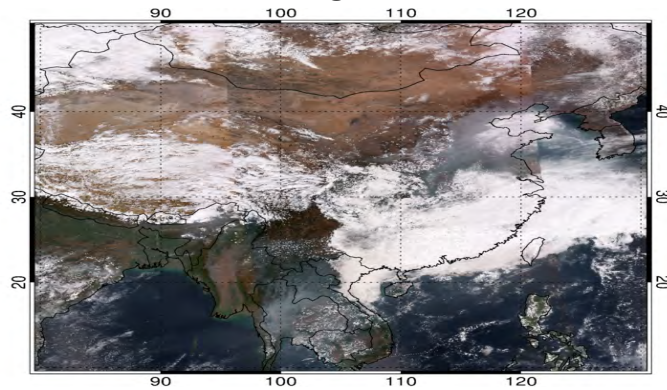


- Implementation of consistent nonspherical dust model in both over-land and over-ocean VIIRS Deep Blue retrieval algorithms substantially improves the angular dependence of retrieved AOD bias, leading to smoother distribution of AOD across the land/sea boundary compared to MODIS

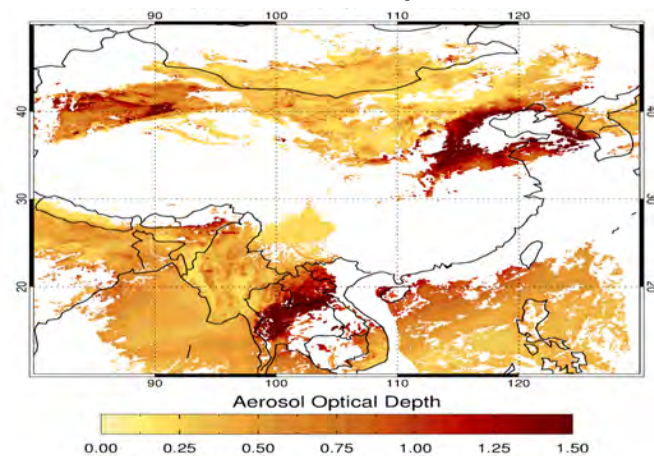
Reference: [Lee et al., 2017, JGR, "Effects of nonspherical dust optical models on the VIIRS Deep Blue over-water aerosol product"](#)

Adding Aerosol Type Product into the Deep Blue Data Suite

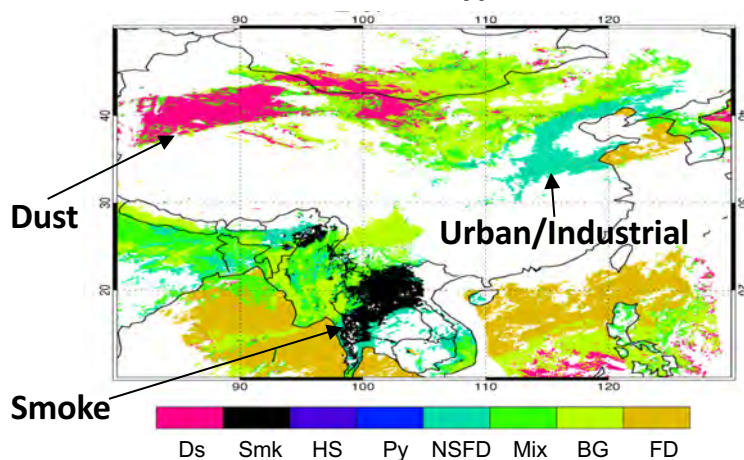
VIIRS RGB image 3/8/2014



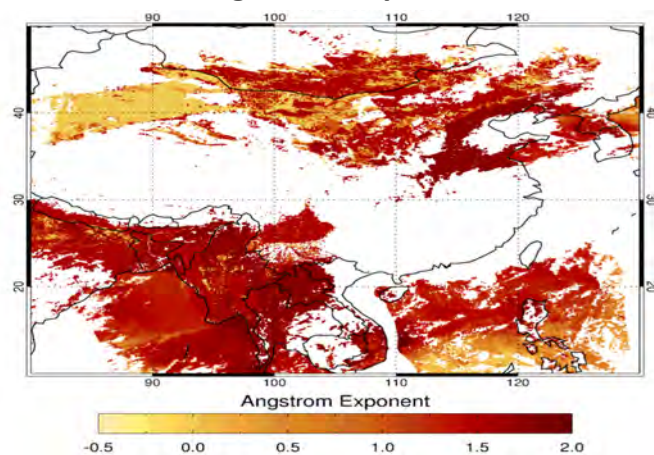
AOD at 0.550 μm



Aerosol Type



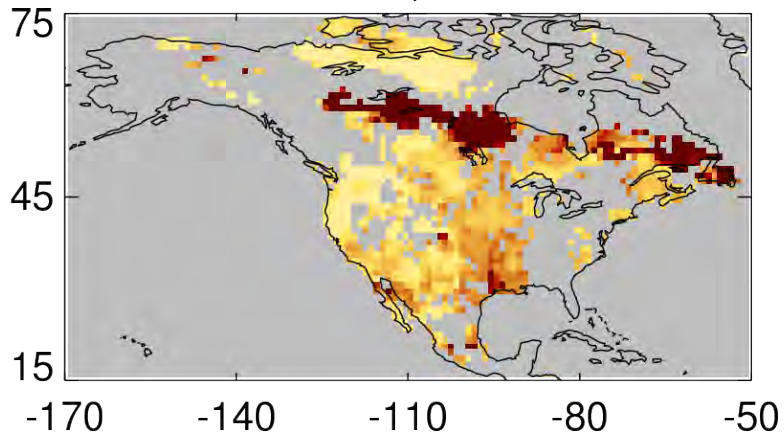
Angstrom Exponent



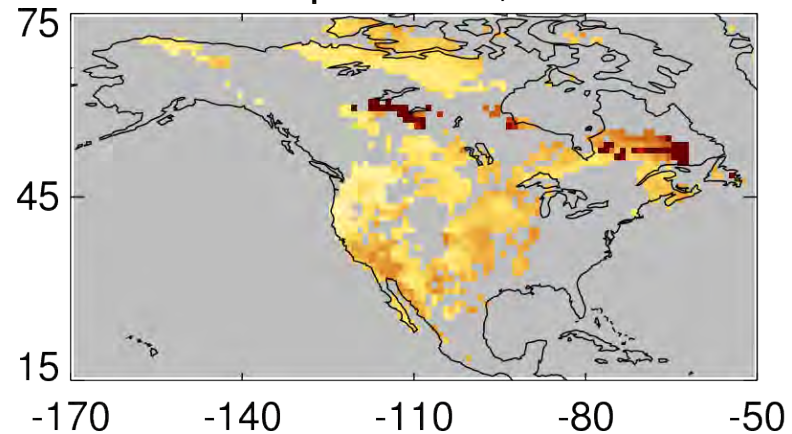
- By taking advantage of the **spectral curvature approach** due to the light absorption of **biomass burning smoke aerosols** at the **blue wavelengths**, we are able to distinguish smoke aerosols from other fine mode aerosols such as urban/industrial aerosols;
- Aerosol type information is derived by combining this smoke mask with retrieved AOD and Angstrom Exponent.

- Improved VIIRS heavy smoke/cloud detection scheme significantly increases the spatial coverage of the retrieved AOD compared to MODIS C6 over major smoke plumes

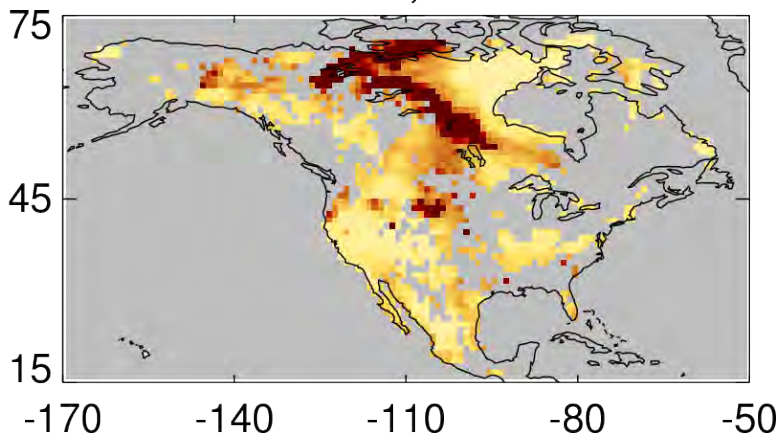
VIIRS AOD, 20130704



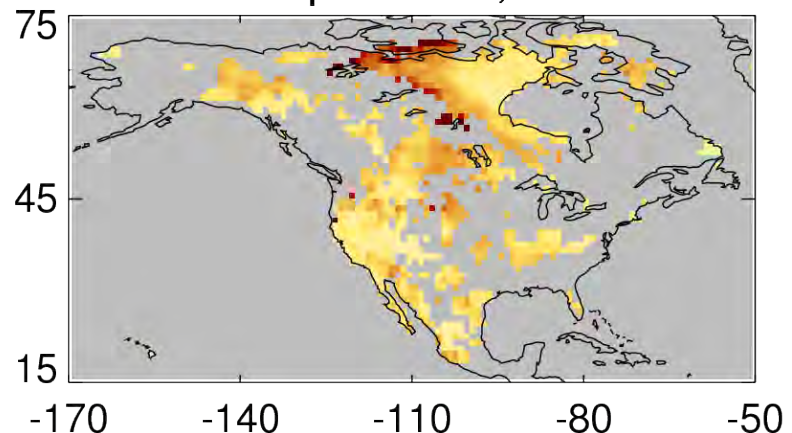
MODIS Aqua AOD, 20130704



VIIRS AOD, 20130814

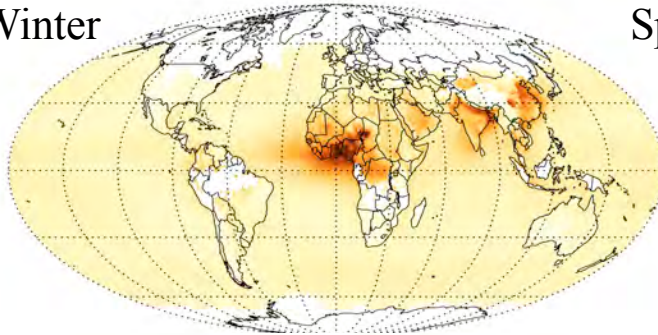


MODIS Aqua AOD, 20130814

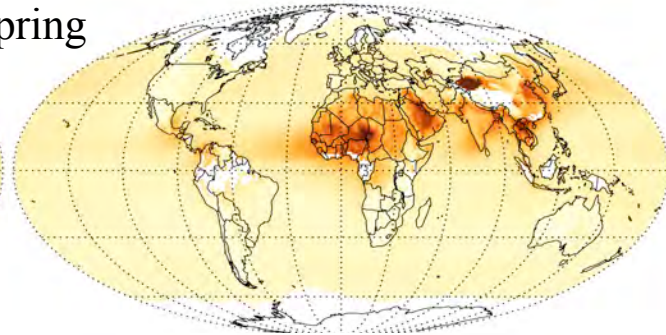


VIIRS 2012-2016 Seasonal 550nm AOD Maps

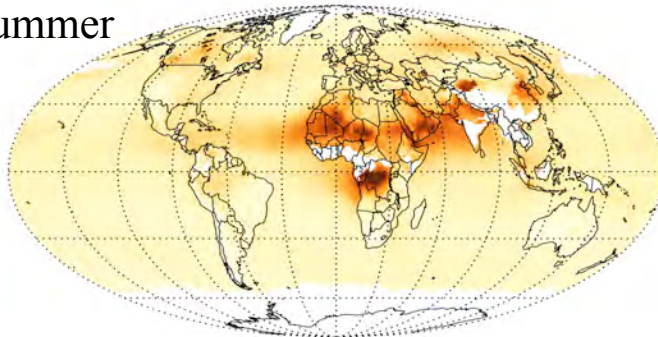
Winter



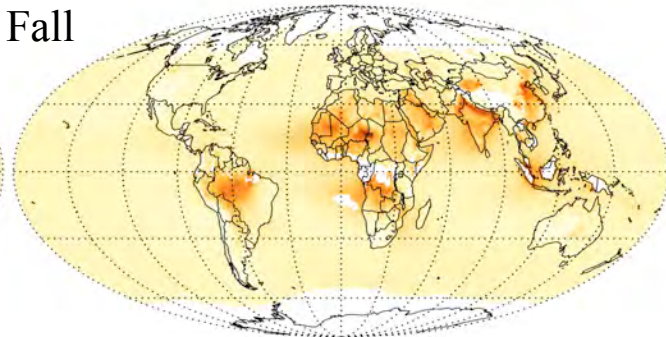
Spring



Summer

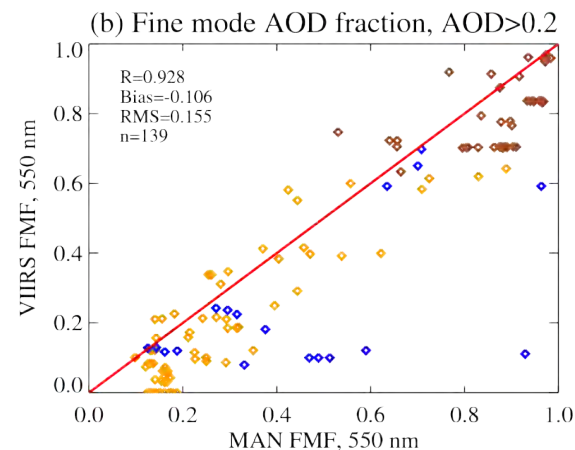
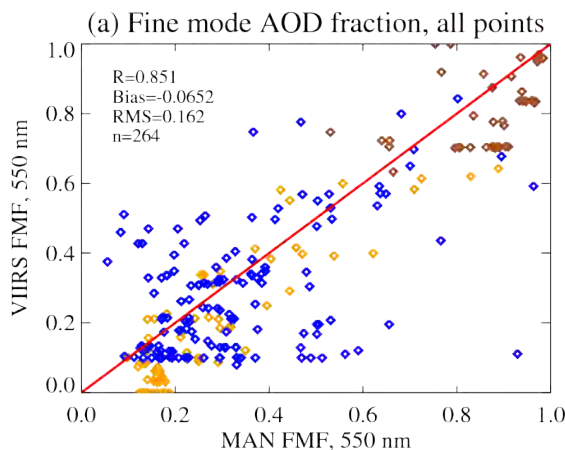
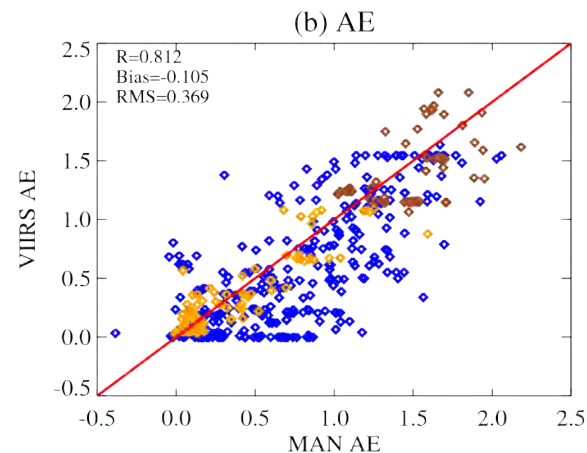
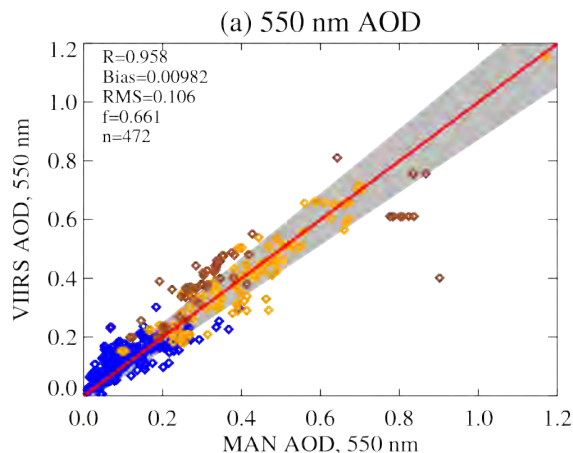


Fall

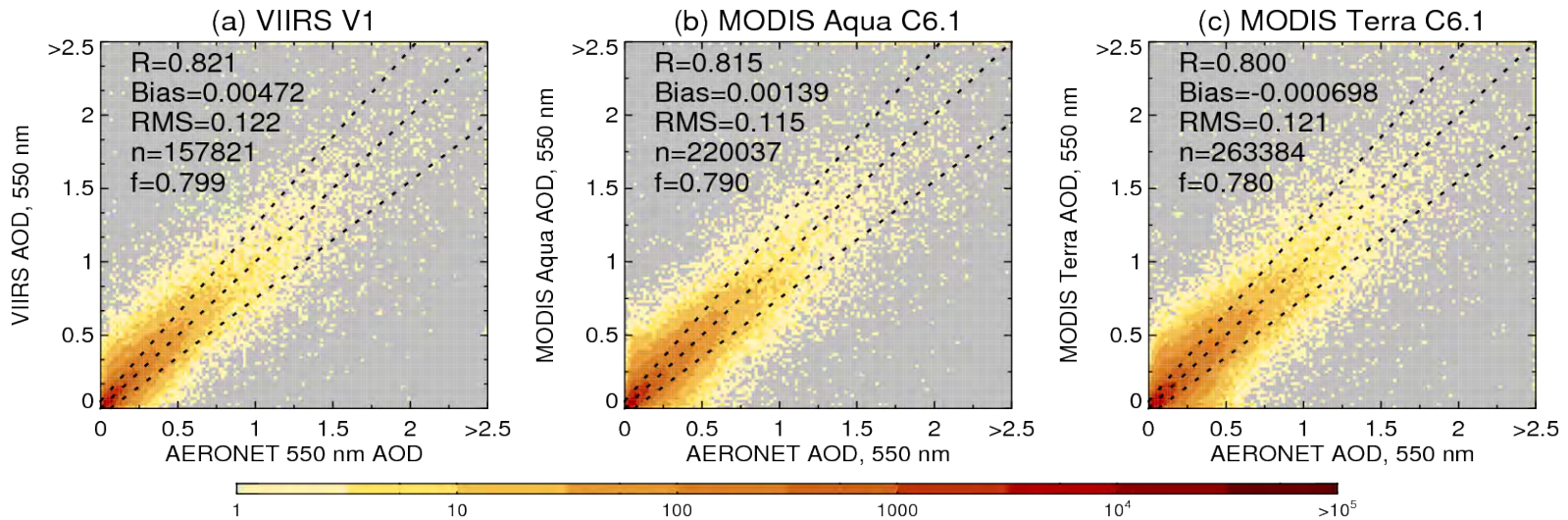


Comparisons of VIIRS over-ocean products with Maritime Aerosol Network (MAN)

- AOD retrieval quality similar to, or better than, standard MODIS product
- Ångström exponent (AE) and fine mode AOD fraction compare favorably to MAN data, even when the AOD is not high
- Colors indicate aerosol optical model: retrieved, not prescribed
 - Either **marine**, **dust**, or **fine-dominated**



Comparisons of VIIRS, MODIS/Terra, MODIS/Aqua over-land products with AERONET

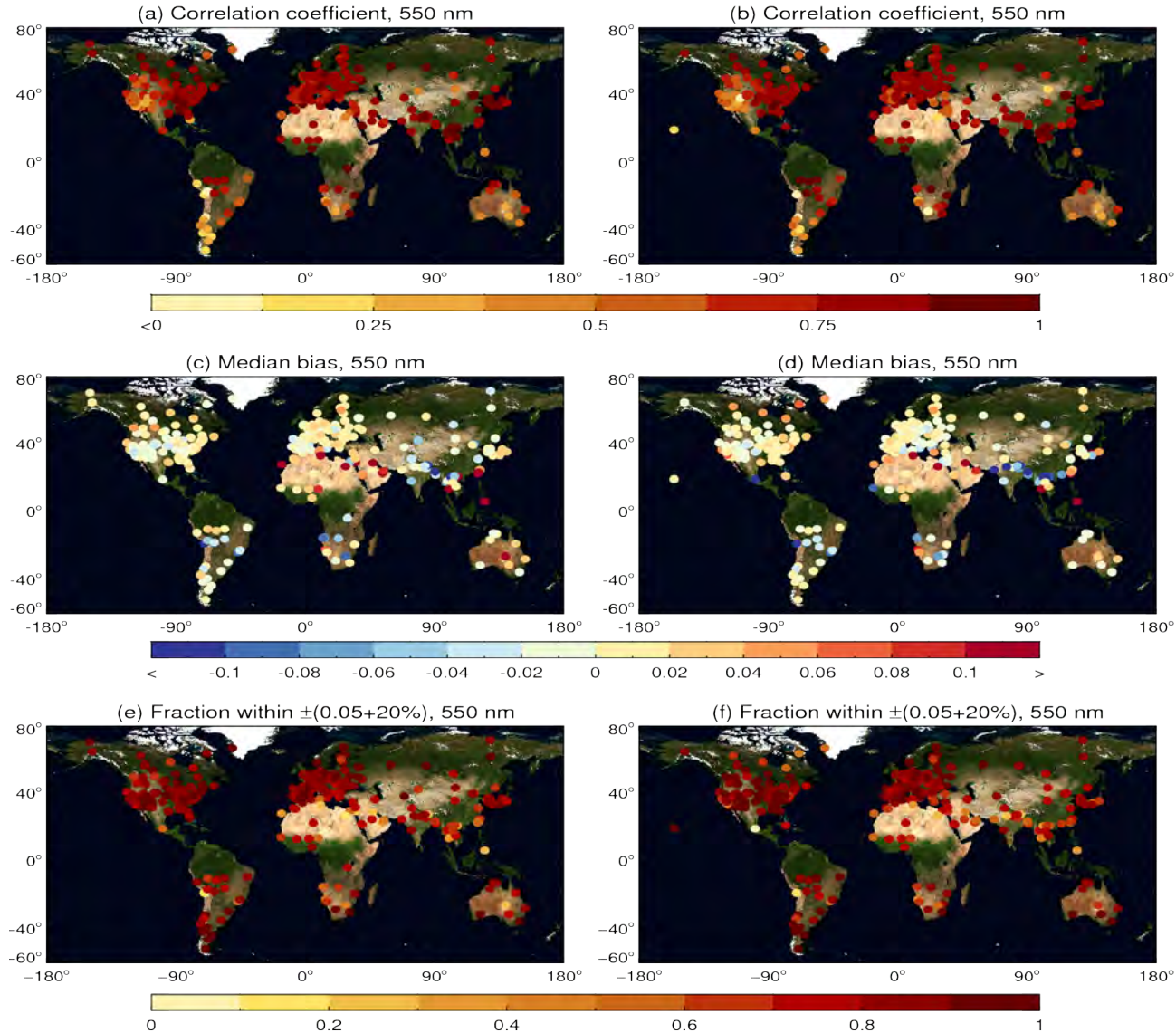


- The performances of the VIIRS V1, MODIS/Aqua C6.1, and MODIS/Terra C6.1 Deep Blue AOD product against the AERONET on global scale are comparable. The percentage of the data that fall within the expected error of $\pm(0.05+20\%)$ is slightly better for VIIRS V1 (~80%), compared to MODIS C6.1 (78% for Terra and 79% for Aqua).

Site-by-Site Comparisons of VIIRS and MODIS/Aqua over-land products with AERONET

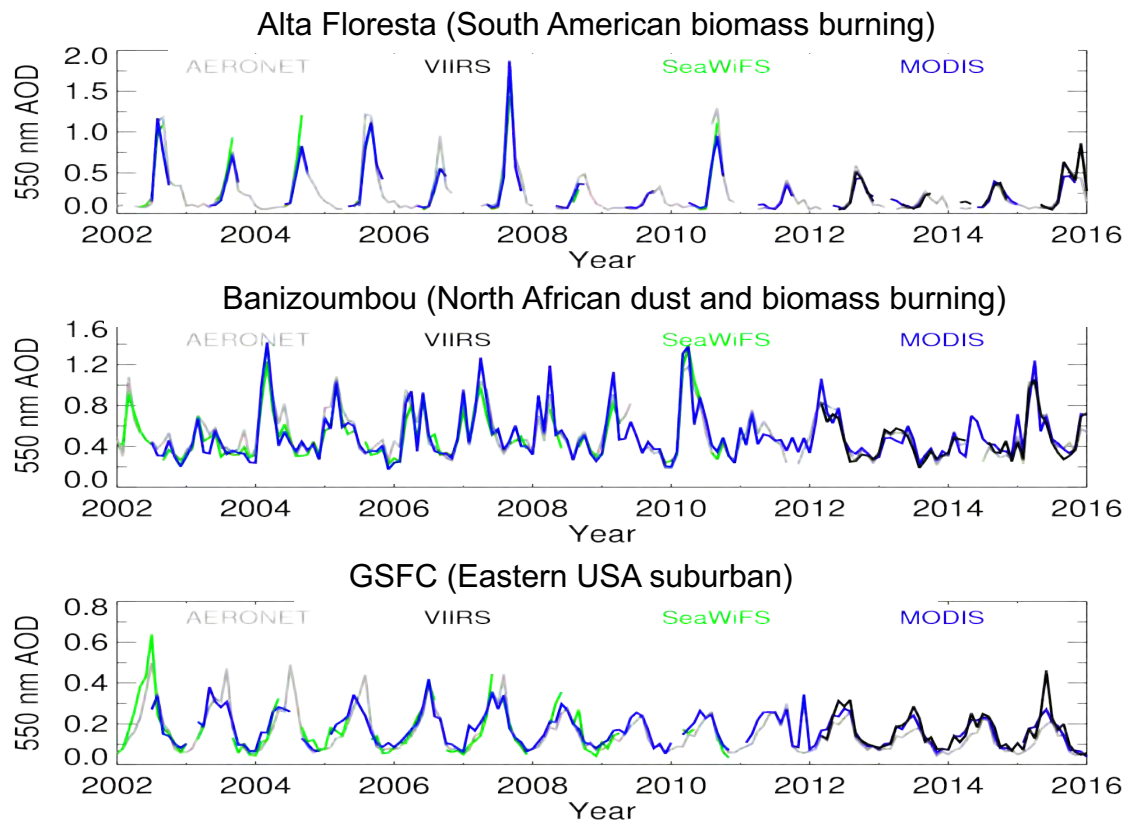
VIIRS (S-NPP) Deep Blue V1

MODIS (Aqua) Deep Blue C6.1





Time Series of Monthly Mean AOD from Multi-satellite Deep Blue data at select AERONET sites

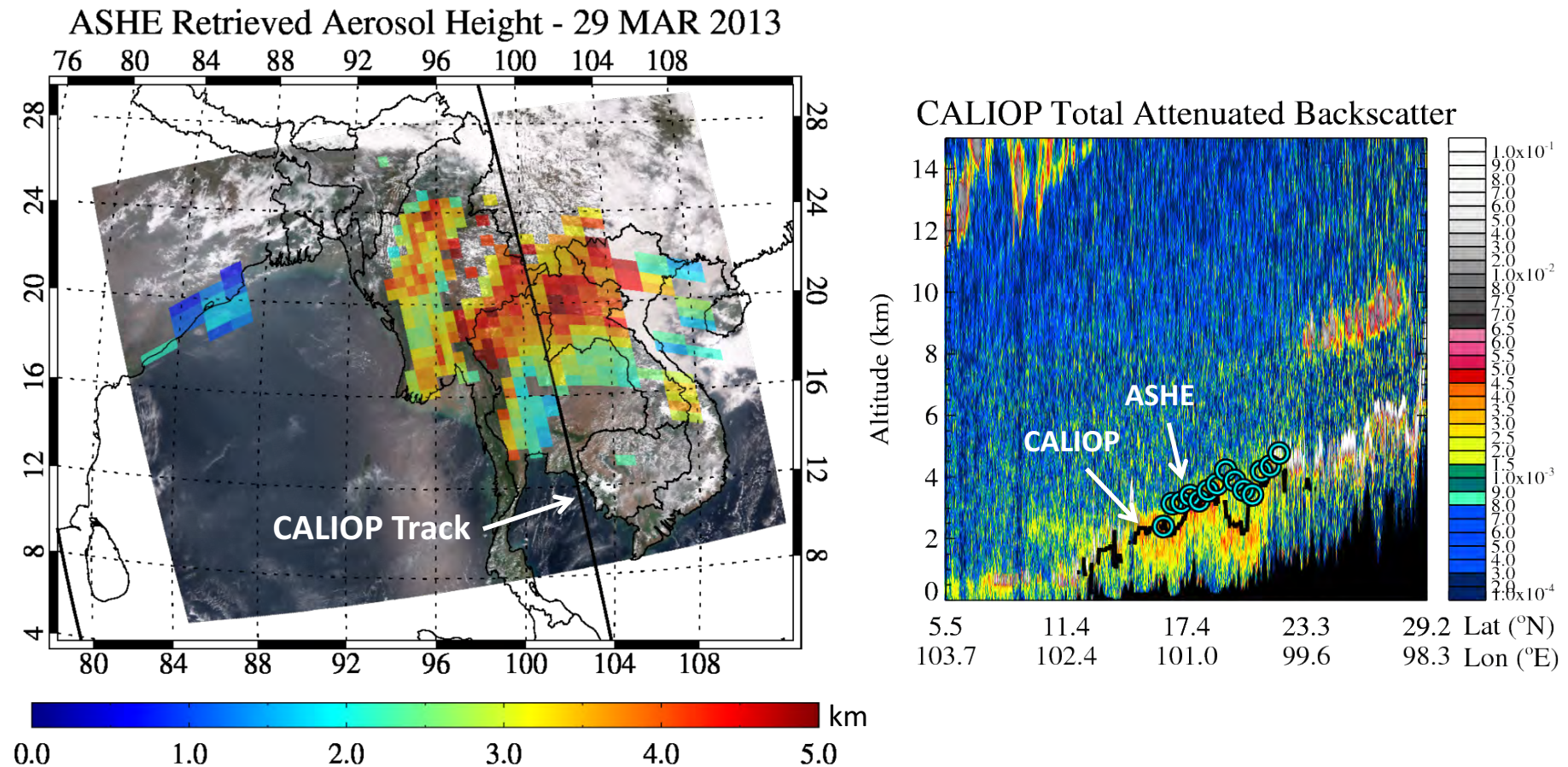


This comparison shows multi-year (2002-2015) quantitative consistency of the VIIRS AOD in comparison with our heritage MODIS and SeaWiFS results, as well as AERONET validation data.

These VIIRS AOD data are generated using corrected VIIRS L1B files after we assessed the calibration of S-NPP VIIRS against MODIS Aqua and developed a cross-calibration correction for VIIRS, which was shown to decrease the uncertainty in retrieved AOD and make VIIRS results more comparable to MODIS.

New Aerosol Plume Height Products For VIIRS and MODIS

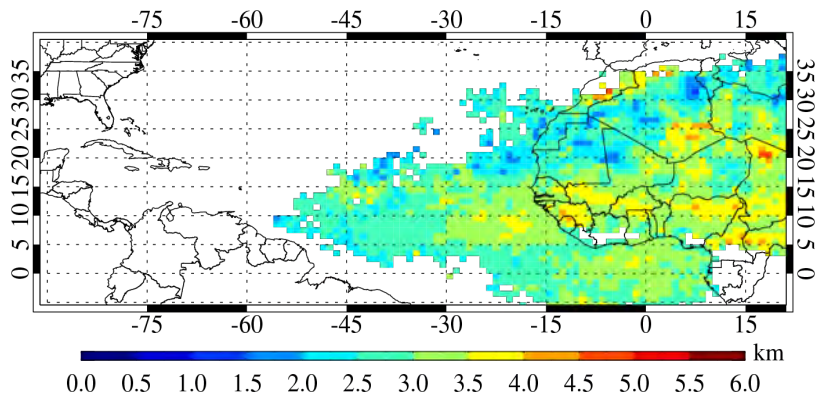
New VIIRS Deep Blue Aerosol Product: Aerosol Plume Height



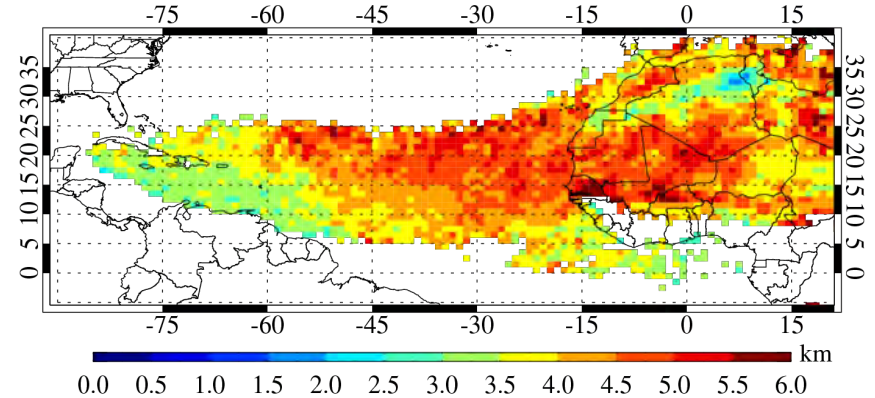
- Left panel shows retrieved aerosol height from our ASHE algorithm, for Southeast Asian biomass burning.
- ASHE combines our VIIRS Deep Blue data with OMPS observations to determine aerosol height, which can not normally be retrieved using this type of sensor
- Validation with CALIOP profiles shows good agreement (right panel)

Seasonal Variation of the Saharan Dust Plume Height

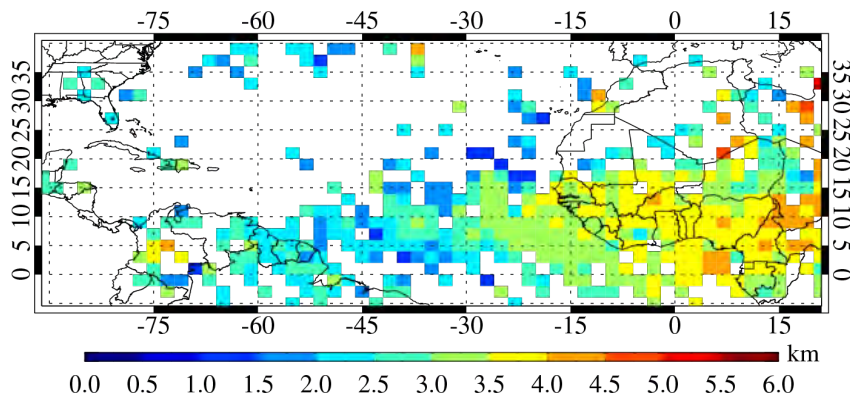
ASHE Aerosol Height (March 2012-2017)



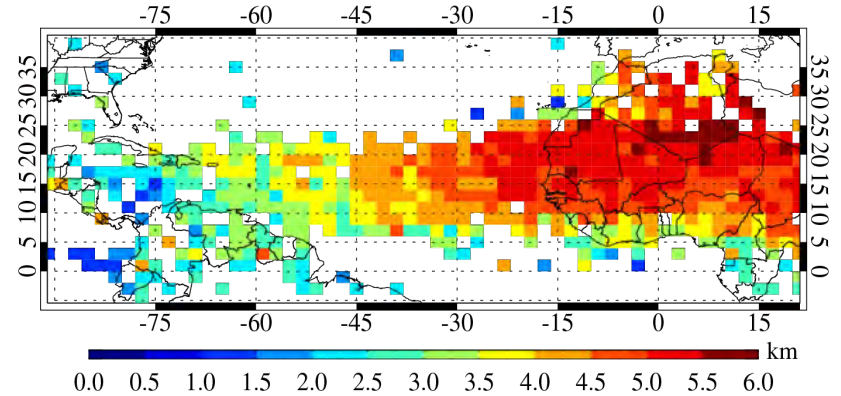
ASHE Aerosol Height (June 2012-2017)



CALIOP (March 2012-2017)



CALIOP (June 2012-2017)

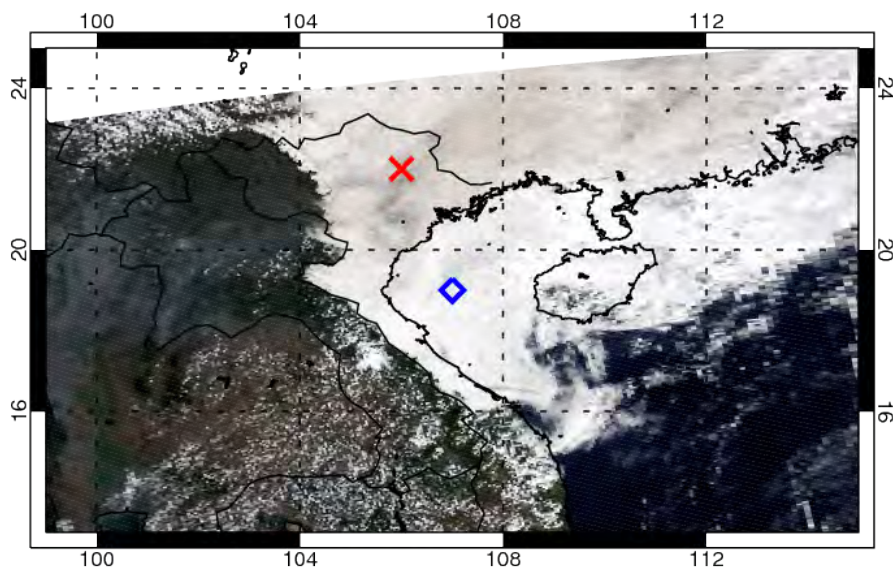


- The ASHE retrieved product provides daily spatial coverage (outside the sun-glint regions) of the Saharan dust plume information across the Atlantic Ocean. Based upon the ASHE analysis results (top), the summertime dust altitudes are generally higher than the springtime ones, which are consistent with the CALIOP observations (bottom).
- Please see our poster for more details: [Lee et al., Aerosol plume height climatology from synergistic use of VIIRS, OMPS, and CALIOP](#)

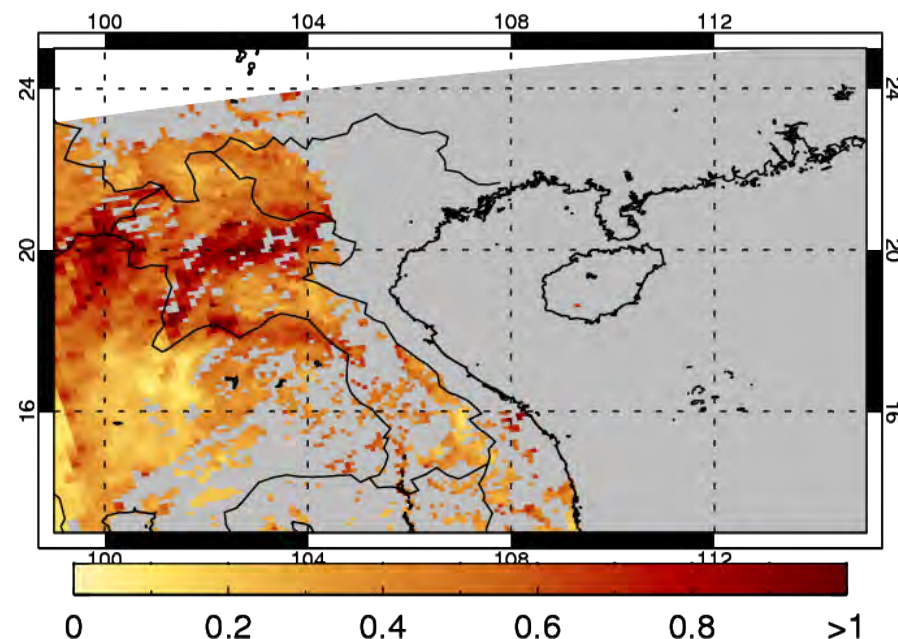
**Extend *Deep Blue* Aerosol Products from
Cloud-free to Cloudy regions**

We can use sensors like MODIS and VIIRS to quantify absorbing aerosols above clouds (AACs)

MODIS Aqua, 06:25 Mar 06 2009



Clear-sky Clear-sky AOD Cloud AOD

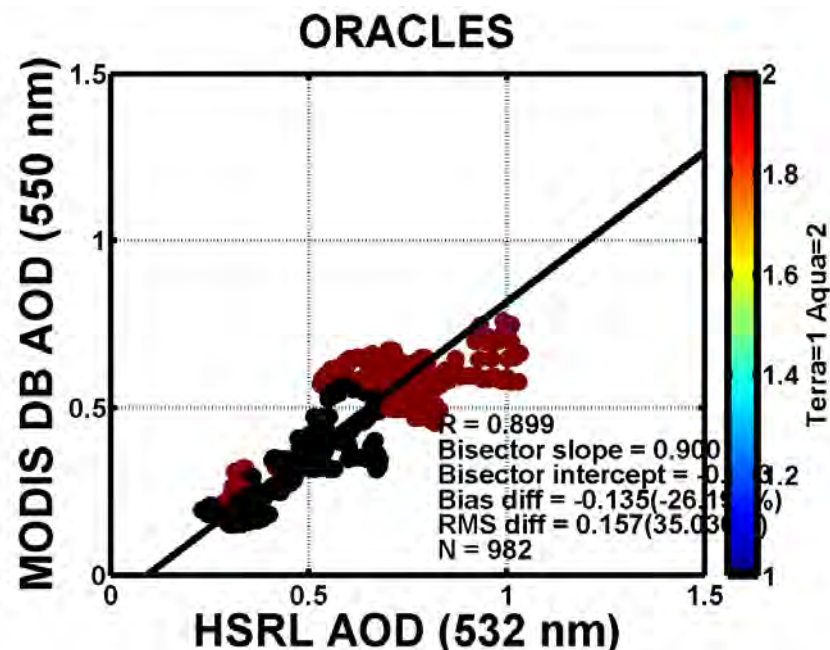
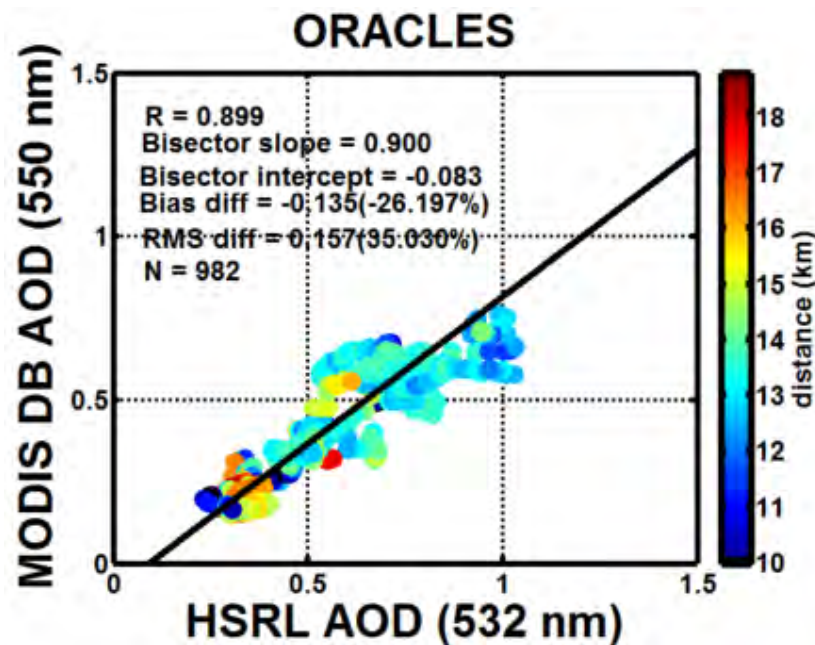


AACs **darken** clouds, and **change the spectral shape** of TOA reflectance

With some assumptions, we can retrieve the **above-cloud AOD** and an estimate of the **COD** of the underlying liquid water cloud

Reference: [Sayer et al., 2016, JGR, “Extending “Deep Blue” aerosol retrieval coverage to cases of absorbing aerosols above clouds: Sensitivity analysis and first case studies”](#)

ORACLES data have greatly expanded our available validation



HSRL-2 data from ORACLES 2016 (data and images courtesy R. Ferrare and S. Burton, NASA LaRC)

Left: AOD scatter plot, coloured by distance between observations

Right: AOD scatter plot, for Terra (black) and Aqua (red)

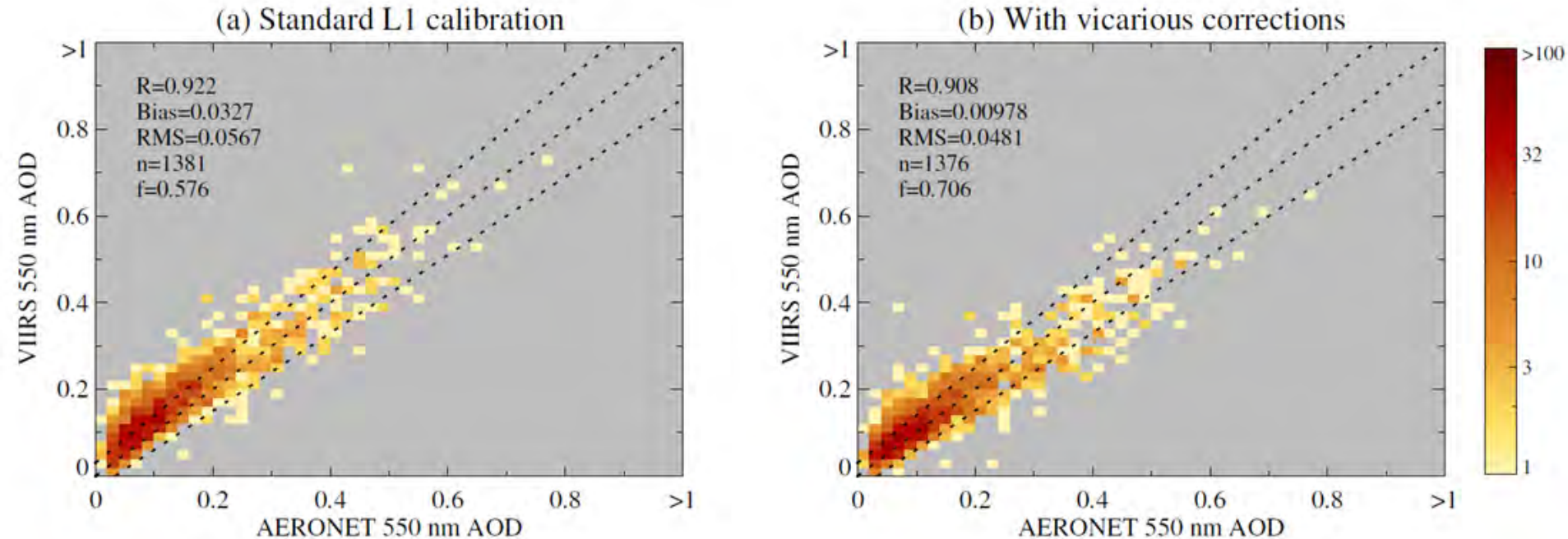
Broadly consistent with AATS comparison results; covers larger range of AOD



Summary

- Based upon the comparisons with AERONET AOD global observations, the expected error for VIIRS DB is $0.05 \pm 20\%$ over land and $0.03 \pm 10\%$ over ocean, which is comparable to that for MODIS DB. The AOD time series from VIIRS and MODIS are consistent with each other.
- The Version 1 VIIRS Deep Blue algorithm was delivered to SIPS in late June. Thanks for the support from Atmosphere SIPS and LAADS, VIIRS DB aerosol products will be ready for release soon.
- We have started implementing aerosol plume height and aerosol above cloud retrievals into the Deep Blue algorithm for VIIRS and MODIS . Several papers that describe retrieval algorithms and preliminary validation results have been published in peer-reviewed journals.

Effects of VIIRS Vicarious Calibrations on AOD retrievals



- **Cross-calibration against collocated MODIS Aqua pixels over dark water scenes with common geometry**
 - Sensor-to-sensor differences accounted for in radiative transfer calculations
 - Technique is independent of the AOD retrieval algorithm
 - Stability of both sensors over the 2012-2016 time series seems (mostly) good
- **Applying these corrections removes the bulk of the AOD bias over water**
 - Suggest MODIS absolute calibration is closer to the truth than VIIRS
 - We are currently repeating this procedure using VIIRS version 2 L1B data

Reference: [Sayer et al., 2017, AMT, "Cross-calibration of S-NPP VIIRS moderate resolution reflective solar against bands MODIS Aqua over dark water scenes"](#)